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Assessing the Hospitals' Preparedness Against COVID-19: A Hybrid Multi-Criteria Decision-Making Approach

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ABSTRACT

Background: COVID-19 pandemic, the different mutations of the virus, and the emergence of different variants requires that hospitals upgrade their levels of preparedness in managing the crisis. This study aims to provide a method for assessing the level of hospitals' preparedness in dealing with such situations.

Methods: In the initial stage, effective criteria for assessing hospital preparedness were identified through literature review. Following that, the Delphi method was used to obtain the perspectives of 40 experts from the healthcare system in order to validate the criteria. Then, the SWARA (Stepwise Weight Assessment Ratio Analysis) technique was applied to determine the weights of the criteria. Through MABAC (Multi-Attributive Border Approximation Area Comparison) technique, the preparedness of 10 selected hospitals in Tehran was assessed. Finally, using sensitivity analysis, the robustness and reliability of the proposed method were examined.

Results: Results indicated that personnel, their education and work experience, medical equipment, and the emergency networks were critical factors in determining the level of hospital preparedness against COVID-19. Out of the 10 selected hospitals, the Imam Khomeini Hospital was found to have the highest level of preparedness.

Conclusion: This is the first study which recommends a simple and effective tool for assessing the level of preparedness through the hybrid MCDM (Multi-Criteria Decision Making) approach. This tool facilitates the proper allocation of budgets and other resources in strengthening the preparedness of hospitals in handling the situation.

Key words: Preparedness, Crisis, Pandemic, COVID-19, Hospital

Introduction

Unexpected events are one of the challenges of human life. Due to their sudden occurrence, emergency measures are required (1). One such event is the COVID-19 pandemic which began in China in December 2019 and spread rapidly worldwide. Given the nature of the crisis and the vital role of hospitals in these conditions, as well as the impact of the crisis on them, hospitals are among the key organizations involved in addressing such epidemics (2). COVID-19 exposed the vulnerability of hospitals in meeting unforeseen events, and showed that national health systems face many obstacles in providing sustainable health services to people. The COVID-19 crisis forced healthcare systems to recognize their shortcomings, and revealed that there is much to be done to improve hospital preparedness (3). Hospitals, therefore, are in dire need of changing their situation and increasing their preparedness against COVID-19 and similar potential crises. As such, it is important to identify and evaluate critical factors determining the level of hospital

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preparedness and use them for developing appropriate solutions aimed at overcoming any shortcoming (4).

Hospital preparedness is a multidimensional term including various elements such as medical equipment, hospital buildings, medical staff and other related factors (5). A review of literature indicates various frameworks and checklists being used in assessing the preparedness of hospitals in the face of disasters and catastrophes. For example, the World Health Organization (WHO) has introduced the SHED (safe hospitals in emergencies and disasters) checklist for evaluating hospitals, which includes three criteria, i.e., structural preparedness, non-structural preparedness, and functional preparedness (6). Structural preparedness indicates the resilience of hospitals in the event of natural disasters, while non-structural preparedness means the preparation of medical equipment. Functional preparedness involves the ability of hospitals to maintain their proper functioning in critical situations such as lack of medicine, food, etc. This checklist comprises 17 dimensions and 139 indicators. Shah *et al.* (7) assessed the vulnerability of six villages in Pakistan during flood from the abovementioned three perspectives. In another study, 36 criteria from six categories of buildings, equipment, communications, transportation, personnel, and flexibility were used to assess the preparedness of Turkish hospitals (8). The review of literature suggests that past research has focused primarily on hospital preparedness in the event of natural disasters such as floods, earthquakes, or wars, whose necessities are different from the COVID-19 outbreak. Due to the COVID-19 pandemic, limited research has been conducted in evaluating and prioritizing factors on hospital preparedness for responding to the virus. For example, Moheimani *et al*. (9) proposed a framework comprising 13 indicators for assessing the preparedness of 25 hospitals in handling the COVID-19 pandemic. However, their focus was solely on performance criteria and excluded other important elements such as the preparedness of hospital equipment. Therefore, the aim of this study was to evaluate the preparedness of selected hospitals in Tehran against COVID-19 pandemic using the multi-criteria decision-making (MCDM) technique.

Materials and Methods

MCDM methods are increasingly used for prioritizing issues in the healthcare sector (10). These methods lead to a more clear and consistent decision by reducing decision makers' bias (11). The method proposed in this study for assessing hospital preparedness against COVID-19 is based on an integrated four-stage approach. In the first stage, the effective criteria and sub-criteria in assessing the preparedness of hospitals were identified through a review of the relevant research. The second stage aimed at validating the criteria and applying the Delphi method to obtain the perspectives of 40 experts in the healthcare system. In the third stage, the SWARA technique was applied to determine the weights of the criteria and sub-criteria. Finally, the MABAC technique was used to assess the readiness of 10 selected hospitals in Tehran. At this stage, the hospital with the highest level of preparedness was identified. The details of each of these methods are described as follows:

SWARA

SWARA is one of the new MCDM methods used in 2010 to analyze reasonable differences between criteria and their weights (12). The simplicity and low number of calculations of this method have led to its widespread use in decision-making in various fields, including healthcare. In this method, experts first rank the criteria in order of importance (13) based on their tacit knowledge, information and experience. Then, using the average value of group rankings obtained, the weight of each criterion is determined. The weight of each criterion indicates its importance. The SWARA steps are described as follows:

Step 1: Rank the criteria according to their importance. The most important criterion is placed in the first rank, the lowest in the last rank, and

other criteria are placed in the middle interval between the two based on their importance.
Step 2: Determine the comparative importance of the mean score of the weights (S_j). Regarding the second-order criterion, it is necessary to determine their importance, comparing the C_j criterion with the C_{j+1} criterion.

Step 3: Calculate the k_j coefficient for each criterion using Equation (1).

$$k_j = \begin{cases} 1 & j = 1 \\ s_{j+1} & j > 1 \end{cases} \quad (1)$$

Step 4: Measure the criteria weights again (q_j) with Equation (2).

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{q_{j-1}}{k_j} & j > 1 \end{cases} \quad (2)$$

Step 5: Calculate each criterion's weight through Equation (3), so that their sum is equal to one.
Where w_j indicates the relative weight of the criterion *j*.

$$w_j = \frac{q_j}{\sum_{k=1}^{m} q_j} \quad (3)$$

MABAC
The MABAC technique in MCDM was introduced in 2015 and was first used in selecting the sources of transportation, and loading and unloading cargo at logistics centers (14). To date, extensive applications of this technique in resolving issues in various fields have been reported (15). The application of this technique involves the following six steps:

Step 1: Form the initial decision matrix. Here, the performance of *m* alternative is evaluated according to the *n* criteria. The alternatives are denoted by the vector A_i, and x_{ij} represents the values of the decision matrix and demonstrates the value of alternative *i* (*i* = 1,2,…,*m*) in the criterion *j* (*j* = 1,2,…, *n*).

Step 2: Normalize the initial decision matrix. Criteria representing benefits (positive) and costs (negative) are normalized using Equations (4) and (5), respectively.

$$t_{ij} = \frac{x_{ij} - x_j^-}{x_j^+ - x_j^-} \quad (4)$$

$$t_{ij} = \frac{x_{ij} - x_j^+}{x_j^- - x_j^+} \quad (5)$$

where t_{ij} represents the values of the normal matrix, and x_j^+ and x_j^- the maximum and minimum values of the alternatives in the *j* criterion, respectively.

Step 3: Calculate the weighted normal matrix with Equation (6).

$$v_{ij} = (1 + t_{ij}) \times w_j \quad (6)$$

where v_{ij} represents the values of the weighted normal matrix.

Step 4: Determine the border approximation area matrix through Equation (7).

$$g_j = \left(\prod_{j=1}^{m} v_{ij} \right)^{\frac{1}{m}} \quad (7)$$

where g_j represents the approximate border area of the *j* th criterion.

Step 5: Calculate the distance matrix from the border approximation area with Equation (8).

$$q_{ij} = v_{ij} - g_j \quad (8)$$

Where q_{ij} is the distance of alternative *i* from the border approximation area of the *j* criterion.

Step 6: Calculate the matrix of the total distance of each alternative from the border approximation area with Equation (9), and rank the alternatives:

$$S_i = \sum_{j=1}^{n} q_{ij} \quad (9)$$

where S_i represents the sum of the distance of alternative *i* from the *n* criterion. Finally, the alternatives are ranked in ascending order based on the S_i value.

Results
Identifying and determining the criteria weights
Based on the literature review, the effective criteria for assessing the hospitals' preparedness in dealing

with COVID-19 were identified. The 18 criteria identified from previous studies were divided into five categories (see Table 1). In the second stage, in order to validate the criteria, the Delphi method was implemented based on the views of experts including physicians and nurses working on the COVID-19 front lines in Tehran hospitals. In this phase, a preliminary and semi-structured questionnaire was provided to the panel of experts. In the second round of Delphi process, closed questionnaires on the Likert scale and based on the results of the first Delphi process were provided to the expert group. After collecting and merging the opinions of the experts, the average of all the factors in the questionnaire were found to be in the medium to high range. The Delphi results confirmed the validity of the identified criteria and the classifications made by the experts. In addition, to evaluate the reliability of the questionnaire, the Cronbach's coefficient was calculated using $SPSS_{26}$. The coefficient value for each and all criteria was found to be higher than 0.7. This means that the questionnaire had acceptable reliability.

Following the identification and validation of the hospitals' preparedness criteria in dealing with COVID-19 based on SWARA, the third stage involved prioritizing and determining their individual weights. The results are presented in Table 2. Based on the experts' judgment, the criterion of the number of personnel (P1) came first, having more weight and importance, while the lowest rank with the least weight and importance belonged to the criteria of the capacity (B3) and number of floors (B4).

Ranking of hospitals

In the fourth stage, the preparedness of 10 selected hospitals in Tehran was evaluated using the MABAC technique. The hospitals active during COVID-19 pandemic were Rasoul Akram (H1), Children's Medical Center (H2), Chamran (H3), Imam Khomeini (H4), Loghman Hakim (H5), Imam Hossein (H6), Masih Daneshvari (H7), Trita (H8), Ali Asghar (H9) and Mostafa Khomeini (H10). The initial decision matrix was then developed based on the hospitals' facilities and infrastructures. Following that, the level of preparedness for the criteria of quality using the Likert scale (very low = 1; low = 2; moderate = 3; high = 4; very high = 5) became quantitative. The criterion of helipad space was also a binary variable which, if available, was 10, and if it was not available, the variable was 1. The characteristics and facilities of the hospitals are presented in Table 3.

Then, the MABAC steps were performed. The distance matrix from the approximate border area, the total distance matrix of each alternative from the approximate border range and the ranking of hospitals are presented in Table 4. According to the results, Imam Khomeini hospital (H4) ranked first, with the highest level of COVID-19 preparedness while Ali Asghar hospital (H9) ranked last, with the lowest level of preparedness against the virus.

Sensitivity analysis

In this section, two analyses were performed on the results. In the first case, the effect of criteria weight on the hospital rankings was investigated, and in the second case, three other MCDM techniques were used to compare the ranking's results. Due to the dynamic and changing nature of COVID-19, the weights of the criteria can be updated and modified by the experts. To investigate these conditions, different scenarios were created to change the weights of the criteria. In the first analysis, in addition to the initial ranking, the following scenarios were considered. The weighted values for each scenario are given in Table 5.

Scenario 1: The weights of the criteria were treated equally and evenly distributed among the relevant sub-criteria.

Scenario 2: All sub-criteria had equal weights.
Scenario 3: Only the hospital building sub-criteria were included and weighed.
Scenario 4: Only the medical equipment sub-criteria were included and weighed.
Scenario 5: Only the personnel sub-criteria were

included and weighed.
Scenario 6: Only the communication equipment sub-criteria were included and weighed.
Scenario 7: Only the transportation sub-criteria are included and weighed.

Using the weights in Table 5, the MABAC steps were performed again. Seven new rankings for hospitals were obtained, the results of which are shown in Figure 1 compared to the initial rankings. The first ranking signifies the hospitals' highest level of readiness against COVID-19. As Figure 1 shows, the change in the weight of the criteria affects the prioritization of hospitals. All hospitals had their rankings changed under all scenarios, although some rankings fluctuated less than others. In other words, the stability of some hospitals such as Imam Khomeini Hospital (H4) and Masih Daneshvari hospital (H7) was higher. For example, Imam Khomeini Hospital (H4) ranked first in five scenarios, which means that it was in a better position than others in terms of the level of preparedness against COVID-19. Imam Hussein Hospital (H6) was ranked fourth in the initial ranking, in second and third scenarios, which means that it had a more stable situation. Ali Asghar hospital (H9) came tenth in the initial ranking, in the first, second, third and fifth scenarios, indicating it was in a lower position in terms of preparedness. The sixth and seventh scenarios, however, had interesting results. In the sixth scenario, which was related to communication equipment, Imam Khomeini Hospital (H4) and Mostafa Khomeini hospital (H10) came in the first and second places, respectively while five hospitals H1, H2, H3, H5 and H6 came in the fourth place. This suggested the relative levels of preparedness regarding communication of these hospitals. Finally, in the seventh scenario, transportation criteria, Chamran (H3) and Imam Khomeini (H4) hospitals were ranked first and second, respectively. This was due to the presence of a helipad space in these hospitals. Moreover, Masih Daneshvari (H7), Imam Hossein (H6) and Mostafa Khomeini (H10) hospitals came jointly in the third place.

In the second analysis, three well-known MCDM techniques, namely COPRAS, EDAS and CoCoSo, were used to rank the hospitals, which was compared with the MABAC results. The steps and calculations for these three techniques are not presented and information on the COPRAS, EDAS, and CoCoSo methods can be found in (16), (17) and (18), respectively. To perform these analyses, the weights obtained in the previous section were used. The COPRAS, EDAS, and CoCoSo techniques provide decision-makers with an analytical approach to determine the best option regarding complex decisions or ranking options. The order of priority of hospitals based on the results of these techniques is shown in Figure 2. For flexibility, the value of λ is 0.5 in CoCoSo. According to the results, Imam Khomeini hospital (H4) was ranked first with respect to all three techniques. This was the highest level of preparedness among the studied hospitals. In addition, Ali Asghar hospital's (H9) ranking under all three techniques was similar to the initial lowest ranking, meaning it was the least prepared to handle COVID-19 compared to other hospitals. Other hospitals experienced minimal changes in their rankings. This shows that the results were consistent with the initial hospital rankings under the MABAC method. Therefore, after evaluating and comparing the results, it can be concluded that the proposed method in this study has good reliability and the prioritization of hospitals is reasonable.

Table 1. Criteria for hospital disaster preparedness

Criteria	Sub-criteria	Description	References
Hospital building	Physical infrastructure (B1)	Assessing buildings to determine if they are resistant to events such as earthquakes, fires, radiation, nuclear accidents and terrorism	(7, 19–21)
	Capacity (B2)	Hospital capacity in terms of human, medical equipment and areas	(8,19,22)
	Number of floors (B3)	Number of floors in the hospital	(8,21)
	Ventilation (B4)	Evaluating the ventilation capacity of the hospital	(8,20,23)
	Hospital building (B5)	The age of the building indicates the facilities, access and paths between the different rooms in each part of the hospital.	(20,21)
Medical equipment	Medical equipment (E1)	The number and amount of drug supplies, operating room equipment (surgical guns, anesthetic gases, masks and surgical gloves, etc.), medical equipment (syringe, suction devices, serum, etc.), diagnostic equipment (CT scans, MRIs) laboratory equipment (centrifuges, Auto Analyzers, etc.), ward equipment, ventilators, defibrillators, etc.) in emergency situations	(9,22,23)
	Emergency medical equipment (E2)	The quantity and quality of medical equipment available for emergency services	(9,20)
	Number of beds (E3)	Availability and adequacy of beds for patients in disaster situations	(7,8,22)
	Resource supply (E4)	Indicating various sources of funding and equipment required by the hospital	(7,8,22)
Communication equipment	Emergency network (C1)	Ability of hospitals to communicate with disaster response agencies	(4,8)
	Communication tools/devices (C2)	The types and number of hospital communication tools/devices	(4,20,24)
	Emergency medical information system (C3)	Communication flows in a hospital with its partners during a catastrophic event, which indicate how reliable and effective this information is.	(20,22,24)
Transportation	Number of vehicles (T1)	The number of vehicles available to the hospital	(8,19)
	Helipad space (T2)	Availability of helipad space for receiving patients transported by helicopter	(9,20)
	Location access (T3)	Access and routes to the hospital	(8,9,19)
Personnel	Number of personnel (P1)	The number of hospital personnel	(8,23,25)
	Manpower preparedness (P2)	Indicating the level of disaster preparedness regarding employees and their behavior and coordination with each other in the event of an accident	(7,20,24,25)
	Education and work experience (P3)	Education level and work experience certificates for hospital staff in terms of disaster preparedness and their behavior and reaction at the time of accident.	(7,8,25)

Table 2. Determining criteria weights through SWARA

Criteria	P1	E1	P3	C1	P2	B5	E2	B2	T1	T3	C2	E3	E4	C3	B1	T2	B3	B4
Ratio of votes	0.975	0.925	0.9	0.900	0.875	0.875	0.850	0.825	0.825	0.800	0.775	0.775	0.775	0.750	0.725	0.725	0.700	0.700
Rank	1.000	2.000	3.000	3.000	4.000	4.000	5.000	6.000	6.000	7.000	8.000	8.000	8.000	9.000	10.000	10.000	11.000	11.000
S		0.050	0.075	0.075	0.100	0.100	0.125	0.150	0.150	0.175	0.200	0.200	0.200	0.225	0.250	0.250	0.275	0.275
k	1.000	1.050	1.075	1.075	1.100	1.100	1.125	1.150	1.150	1.175	1.200	1.200	1.200	1.225	1.250	1.250	1.275	1.275
q	1.000	0.952	0.930	0.930	0.909	0.909	0.889	0.870	0.870	0.851	0.833	0.833	0.833	0.816	0.800	0.800	0.784	0.784
w	0.064	0.061	0.060	0.060	0.058	0.058	0.057	0.056	0.056	0.055	0.053	0.053	0.053	0.052	0.051	0.051	0.050	0.050

Table 3. Characteristics and facilities of selected hospitals

Hospitals	B1	B2	B3	B4	B5	E1	E2	E3	E4	C1	C2	C3	T1	T2	T3	P1	P2	P3
H1	H	M	H	5	VH	M	M	330	H	H	VH	H	2	0	M	300	VH	M
H2	M	M	H	3	VH	H	H	130	H	H	H	H	2	0	H	160	VH	H
H3	H	H	M	4	H	H	H	110	H	H	H	H	2	1	VH	70	VH	H
H4	VH	H	VH	5	VH	VH	VH	595	VH	H	VH	VH	2	1	H	4000	VH	H
H5	H	M	H	5	VH	M	M	310	VH	H	H	H	2	0	M	200	VH	M
H6	H	H	VH	8	H	H	VH	450	H	H	H	H	2	0	H	220	VH	VH
H7	VH	VH	VH	6	VH	VH	VH	450	H	H	H	VH	4	0	M	400	VH	VH
H8	VH	VH	VH	12	VH	H	H	190	H	M	H	H	1	0	H	350	VH	H
H9	H	M	M	2	H	M	H	80	H	H	VH	H	1	0	H	40	H	H
H10	H	M	H	1	H	H	M	50	VH	VH	H	VH	1	0	VH	50	H	H

**Note*: VH: very high; H: High; M: moderate; L: Low; VL: very low.

Table 4. Results of MABAC for the hospital rankings

Hospitals	**B1**	**B2**	**B3**	**B4**	**B5**	**E1**	**E2**	**E3**	**E4**	**C1**	**C2**	**C3**	**T1**	**T2**	**T3**	**P1**	**P2**	**P3**	S_i	**Rank**
H1	- 0.017	-0.003	- 0.008	0.028	0.006	0.003	- 0.012	- 0.012	0.001	- 0.012	- 0.012	0.003	- 0.008	0.005	- 0.005	0.015	0.002	- 0.017	- 0.062	7
H2	0.012	-0.028	- 0.004	- 0.030	0.006	0.003	- 0.014	- 0.012	0.001	- 0.012	- 0.012	0.003	0.044	0.032	- 0.007	0.015	0.002	0.012	- 0.063	8
H3	0.012	0.023	0.001	0.028	0.036	0.032	0.034	0.041	0.001	0.041	0.040	0.003	0.044	0.005	0.057	0.015	0.002	0.012	- 0.005	5
H4	-0.017	- 0.003	0.001	0.028	- 0.025	- 0.026	0.006	0.041	0.001	- 0.012	- 0.012	0.003	- 0.008	- 0.022	- 0.004	0.015	- 0.028	- 0.017	0.442	1
H5	0.012	0.023	0.015	- 0.030	0.006	0.032	0.020	- 0.012	0.001	- 0.012	- 0.012	0.003	- 0.008	0.005	- 0.004	0.015	0.032	0.012	- 0.066	9
H6	0.041	0.023	0.005	0.028	0.036	0.032	0.020	- 0.012	0.001	- 0.012	0.040	0.041	- 0.008	-0.022	- 0.001	0.015	0.032	0.041	0.079	4
H7	0.041	0.023	0.033	0.028	0.006	0.003	- 0.006	- 0.012	- 0.029	- 0.012	- 0.012	- 0.015	- 0.008	0.005	- 0.002	0.015	0.002	0.041	0.285	2
H8	- 0.017	- 0.028	- 0.013	- 0.030	- 0.025	0.003	- 0.017	- 0.012	0.001	0.041	- 0.012	- 0.015	- 0.008	0.005	- 0.007	- 0.043	0.002	- 0.017	0.087	3
H9	- 0.017	- 0.003	- 0.018	- 0.030	0.006	- 0.026	- 0.020	0.041	0.031	- 0.012	0.040	- 0.015	- 0.008	0.032	- 0.007	- 0.043	0.002	- 0.017	- 0.179	10
H10	- 0.017	- 0.003	- 0.008	0.028	0.006	0.003	- 0.012	- 0.012	0.001	- 0.012	- 0.012	0.003	- 0.008	0.005	- 0.005	0.015	0.002	- 0.017	- 0.050	6

Table 5. Criteria weights for each scenario

Criteria	**Sub-criteria**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**
Hospital building	B1	0.040	0.055	0.200	0.000	0.000	0.000	0.000
	B2	0.040	0.055	0.200	0.000	0.000	0.000	0.000
	B3	0.040	0.055	0.200	0.000	0.000	0.000	0.000
	B4	0.040	0.055	0.200	0.000	0.000	0.000	0.000
	B5	0.040	0.055	0.200	0.000	0.000	0.000	0.000
Medical equipment	E1	0.050	0.055	0.000	0.250	0.000	0.000	0.000
	E2	0.050	0.055	0.000	0.250	0.000	0.000	0.000
	E3	0.050	0.055	0.000	0.250	0.000	0.000	0.000
	E4	0.050	0.055	0.000	0.250	0.000	0.000	0.000
Communication equipment	C1	0.066	0.055	0.000	0.000	0.000	0.333	0.000
	C2	0.066	0.055	0.000	0.000	0.000	0.333	0.000
	C3	0.066	0.055	0.000	0.000	0.000	0.333	0.000
Transportation	T1	0.066	0.055	0.000	0.000	0.000	0.000	0.333
	T2	0.066	0.055	0.000	0.000	0.000	0.000	0.333
	T3	0.066	0.055	0.000	0.000	0.000	0.000	0.333
Personnel	P1	0.066	0.055	0.000	0.000	0.333	0.000	0.000
	P2	0.066	0.055	0.000	0.000	0.333	0.000	0.000
	P3	0.066	0.055	0.000	0.000	0.333	0.000	0.000

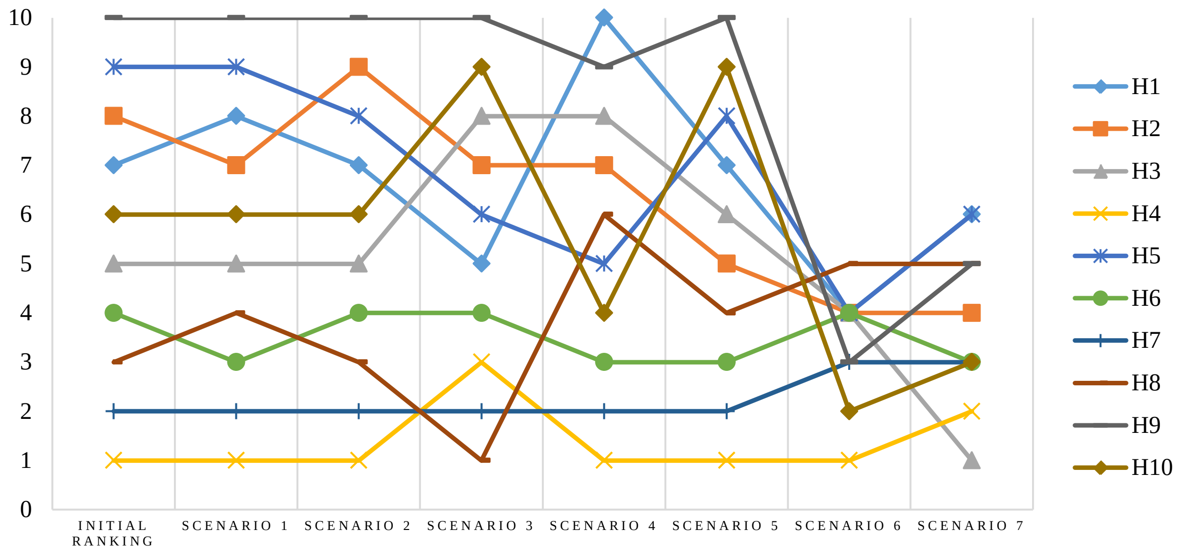

Figure 1. Ranking of hospitals according to different scenarios

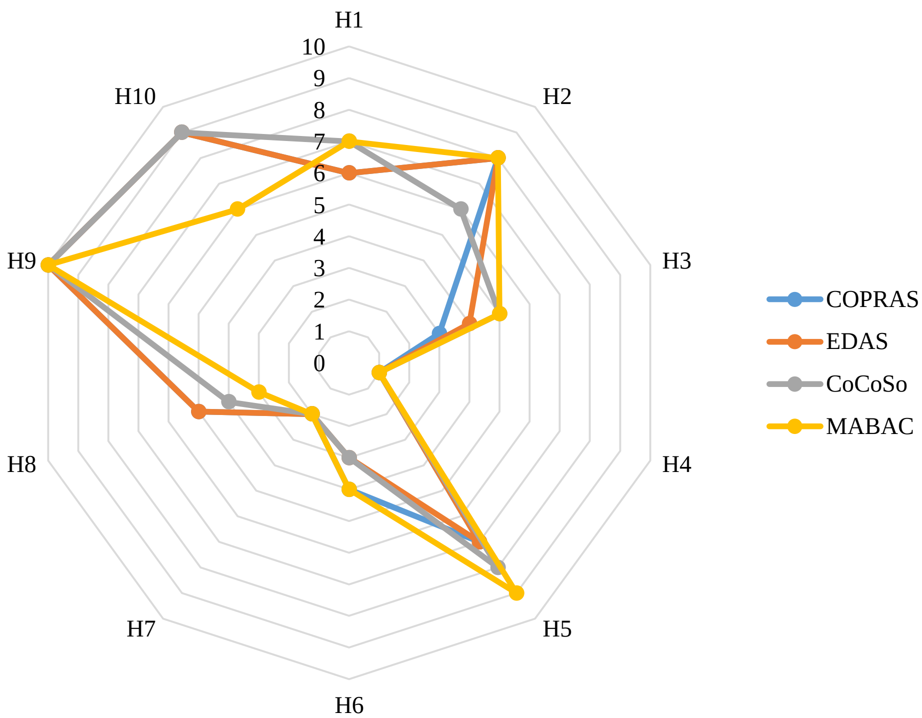

Figure 2. Results of different techniques for the hospital rankings

Discussion

The process of preparing hospitals is not a simple and linear process. It involves much complexity and is influenced by various infrastructural, scientific, medical, political, social, economic and other factors. Based on the research background and expert opinions, the relationships between the factors affecting the level of hospital preparedness are such that the structure of the problem becomes a network structure with interdependencies. Decision-making methods can be a good solution to address such questions, and the MCDM methods used in this study can be useful for this purpose. The results of the SWARA technique show the number of personnel (P1), medical equipment (E1), and education and work experience (P3) indexes ranked first to third, respectively. In addition, manpower preparedness (P2) and hospital building (B5) were jointly ranked fifth in the order of importance. From the study results, it can be seen that manpower is critical in assessing the level of hospital preparedness in facing the COVID-19 pandemic. However, a review of previous studies indicated that according to the type of disaster, the factors related to the preparedness of hospitals can be different. For example, Mulyasari *et al.* (19) evaluated hospital preparedness for earthquakes in eight Japanese cities. Using a questionnaire comprising 6 dimensions and 21 indicators, they examined hospital preparedness from the four perspectives of structural, non-structural, functional and human resources. They concluded that functional preparedness in the peak period of a disaster was a key factor. However, based on the evaluations of the experts in this study, personnel preparedness was determined to be the most important indicator of hospital preparedness against COVID-19 pandemic. In 2017, Dargahi *et al.* (26) conducted a study on the functional preparedness and non-structural safety of health centers at Kermanshah University of Medical Sciences in the face of natural disasters. Their study showed that low scores in insurance coverage and risk reduction measures during disasters were among the significant areas which could help improve operational preparedness at the centers. In another study, Hatami *et al.* (21) examined the functional, structural and non-structural preparedness of Ahwaz health centers for accidents form 2014 to 2015. Their study revealed that the centers had the least preparedness for natural disasters in terms of insurance coverage, food storage, drinking water, and training and practice. Thus, it can be concluded that the importance or ranking of factors related to the preparedness and vulnerability of healthcare centers can vary depending on the crises being faced.

However, the results of this study were more consistent with the findings of Ortiz-Barrios et al. (8) regarding the preparedness of hospitals in Turkey (8). It was also confirmed that the personnel index was the most important factor in assessing the preparedness of hospitals. Marzaleh *et al.*(27) assessed the preparedness of hospital emergency departments against radiation, nuclear accidents, and nuclear terrorism. They evaluated 31 criteria in 3 main categories, namely staff, materials and structure (system). They found employees' preparedness to be of the highest priority. Similarly, a study by Samsuddin *et al.* (28) on disaster preparedness and hospital resilience in Malaysia showed that human resources and training and the ability to adapt in a timely manner are key factors in hospital preparedness . In addition, Moheimani *et al.* (9) in one of the few recent works assessing hospital preparedness during the COVID-19 pandemic, demonstrated that the functional dimension had a significant impact on hospital preparedness; furthermore, adequate medical equipment and beds were critical in increasing preparedness levels. The findings were consistent with the results of this study, which found that medical equipment was the second key factor in hospital preparedness against COVID-19 pandemic. The reasons for the importance of the personnel and medical equipment in COVID-19 pandemic compared to natural disasters can be attributed to the nature of this phenomenon. Due to the unexpected speed of release and frequent peaks, on the one hand, and the need for ventilators for critically ill patients on the other, the preparedness of medical staff and the availability of medical equipment can be more effective than any other factor in dealing with this pandemic.

Conclusion

Different mutations of COVID-19 and the emergence of variants of the virus necessitate enhancing the level of hospital preparedness in handling the situation. Through the literature review and the views of experts, this study identified and prioritized factors related to the preparedness of hospitals in dealing with this virus. Based on the rankings of the criteria, assigning high importance to personnel and medical equipment and proper planning, and allocation of resources will contribute significantly to lessening the impact of this crisis. In addition, according to the identified criteria, the current position of different hospitals can be assessed and solutions to enhance their preparedness level can be provided.

Given the manpower criteria and its importance on the level of preparedness of hospitals against COVID-19, appropriate actions and initiatives should be taken to increase the number of medical staff and maintain ethical issues by meeting their material and spiritual needs. These include facilitating recruitment and employment, rewarding, appreciating the loyalty and dedication of medical staff working in COVID-19 centers, highlighting the health system's efforts in combatting the virus in the media, and inviting retirees to work during peak hours. Moreover, based on the perspectives of research experts on the vital role of medical equipment in dealing with COVID-19, it is recommended that domestic knowledge-based companies be supported and given various incentives to produce essential equipment such as ventilators and personal protective equipment.

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Conflict of interests

The authors declared no conflict of interests.

Authors' contributions

Hosseini Sarkhosh SM and Zahedi M designed research, conducted research, analyzed data; and Hosseini Sarkhosh SM wrote the paper. Hosseini Sarkhosh SM had primary responsibility for final content. All authors read and approved the final manuscript.

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